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ORIGINAL ARTICLE

Effect of interval training on performance in long-distance runners affiliated with Japanese companies

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ABSTRACT

The company-organized sports system in Japan employs athletes as regular staff, allowing them to balance work and sports. This system presents challenges, particularly in terms of limited training time. High-intensity interval training (HIIT), which delivers high training loads in short periods, is essential for these athletes. This study examined the impact of HIIT on the physical and psychological performance of a male long-distance runner, who was an Olympic representative, affiliated with a company. Over a 92-day period, the athlete's performance was assessed through Training Achievement Scores, Physical Conditioning Scores, and Mental Conditioning Scores. Results indicated fluctuations in training and physical conditioning scores, highlighting the need for objective condition assessments and tailored mental conditioning strategies. Enhancing support systems and incorporating HIIT are crucial for athletes to be able to compete at international levels while managing injury risks and environmental stresses.

Keywords: Performance analysis, Company-organized sport, Interval training, Long-distance running, Sport performance.

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INTRODUCTION

The company-organized sports system is a unique aspect of sports in Japan. Under this system, athletes are employed by companies as regular employees or staff members, which allows them to balance their professional work with athletic activities. Among Japanese Olympic athletes, approximately 55% are reported to be company employees, while only about 25% are professional athletes (Yamashita, 2009). Furthermore, in long-distance track events, all male and female athletes ranked in the top eight for the 10,000 m event at the Japan National Championships were affiliated with companies (Federations). Therefore, many long-distance track and field athletes in Japan are active in company-organized sports systems.

A significant disadvantage of the company-organized sports system is the limited training time. Athletes must balance their work and athletic training, which becomes increasingly difficult as they reach higher levels of competition. Therefore, athletes active in company-organized sport require efficient training schedules that maximize effectiveness within a short time.

Long-distance training can be broadly divided into anaerobic exercise, which primarily utilizes the ATP-CP system and glycolytic pathways, and aerobic exercise, which primarily uses oxidative pathways. Traditional Japanese training methods have primarily focused on maintaining a relatively steady pace throughout the race, with an increase in speed during the final stages to secure victory. Therefore, an emphasis has been placed on training at running speeds near the lactate threshold. On the other hand, the top athletes worldwide engage in high-intensity aerobic training to adapt to various race strategies and secure victories (Billat, 2001).

High-intensity aerobic training, otherwise known as interval training, involves repeated high-intensity exercises with recovery periods in between (Billat, 2001). Interval training has been reported to be effective in improving the endurance capacity of athletes (Burgomaster et al., 2005, Gibala et al., 2006). Furthermore, interval training involving repetitions of running at 90–100% of the $\dot{V}O_{2max}$ for 1 to 8 min can improve the $\dot{V}O_{2max}$ and performance in long-distance runners (Fox et al., 1975). Therefore, the introduction of high-intensity interval training (HIIT) is crucial for the training of company athletes within limited time constraints for training. Many previous studies have focused on the effects of short-term or immediate training interventions (Burgomaster et al., 2005, Billat, 2001, Gibala et al., 2006); however, the long-term training effects, in addition to the physical and psychological changes in athletes in coaching environments, following the introduction of interval training have not been clearly elucidated.

Therefore, this study aimed to elucidate the effects of HIIT on both the physical and psychological performance in male long-distance athletes who represented Japan during the Olympics and were affiliated with company teams. We present the case study of an athlete who competed at the Olympics.

METHODS

Participant

The participant was an athlete affiliated with a corporation with a 14-year history in track and field. He competed at 10,000 m in the 2015 IAAF World Championships in Beijing. His personal record was 27:42.71 min. The intervention period for verifying the training effects was 92 days, from May 13, 2016, to August 13, 2016.

Training protocol

The training protocol was constructed by analysing and anticipating race development based on factors such as race day conditions and weather. As such, it was predicted that there would be relatively minimal fluctuations in race pace, with pace becoming notably faster. Consequently, HIIT was introduced (Table 1). The interval training in this study was based on maintaining paces of 31–30 s at 200 m, 62–60 s at 400 m, and 2:45 min at 1000 m. Furthermore, for training sessions involving high physical exertion, specific guidelines were provided regarding the distance or duration of each training session, running speed, and location of implementation to ensure that the athlete could mentally prepare with a clear understanding of the intensity.

Table 1. Training protocol.

Date	Main Training
May 13, 2016	am：Cross country 2500m×6 (8'30)+TR
May 14, 2016	Off
May 15, 2016	Off
May 16, 2016	pm：16000m(3'10 ~ 05)+1000m(2'40) R=400m
May 17, 2016	pm：SP
May 18, 2016	pm：SP
May 19, 2016	**pm：200m×10(30) R=200m(60")**
May 20, 2016	pm：SP
May 21, 2016	Off
May 22, 2016	Race : 5000m 13.54.45 8th （3rd in Japanese）
May 23, 2016	pm：SP
May 24, 2016	pm：SP
May 25, 2016	pm：SP
May 26, 2016	am：25000m (3'30 ~ 20)+TR
May 27, 2016	pm：SP
May 28, 2016	Off
May 29, 2016	Off
May 30, 2016	**pm：1000m×12(2'55) R=200m(55")**
May 31, 2016	pm：SP
June 1, 2016	**pm：400m×7(62) R=200m(65")**
June 2, 2016	pm：SP
June 3, 2016	pm：SP
June 4, 2016	Race : 10000m 28.39.33 1st (Part of Training)
June 5, 2016	Off
June 6, 2016	pm：SP
June 7, 2016	pm：SP
June 8, 2016	pm：SP
June 9, 2016	am：20000m (3'20 ~ 15)
June 10, 2016	am：GA pm：SP
June 11, 2016	am：Free pm：12000m(3'05)+1000m(2'40) R=400m
June 12, 2016	Off
June 13, 2016	am：SP pm：Off
June 14, 2016	**am：Off pm：400m×7(62") R=200m(65")**
June 15, 2016	am：SP pm：Off
June 16, 2016	**am：Off pm：1000m×7(2'47 ~) R=200m(70")**
June 17, 2016	am：SP pm：Free
June 18, 2016	am：Off pm：GA
June 19, 2016	pm：8000m(3'15 ~ 10)
June 20, 2016	pm：SP
June 21, 2016	pm：3000m(8'20)
June 22, 2016	pm：SP

June 23, 2016	am：GA pm：SP
June 24, 2016	Race, 10000m 28.17.51 3rd
June 25, 2016	pm：SP
June 26, 2016	Race : 5000m 13.48.71 8th
June 27, 2016	am：GA
June 28, 2016	Off
June 29, 2016	pm：SP
June 30, 2016	pm：SP
July 1, 2016	pm：SP
July 2, 2016	pm：10000m(3'15 ~ 10)+400m(FREE) R=200m
July 3, 2016	Inauguration ceremony
July 4, 2016	pm：12000m(3'05)+400m(60") R=200m
July 5, 2016	pm：SP
July 6, 2016	pm：SP
July 7, 2016	**pm：1000m×7(2'45) R=200m(65)**
July 8, 2016	pm：SP
July 9, 2016	Off
July 10, 2016	am：GA pm：Free
July 11, 2016	Race, 10000m 27.48.35 2nd
July 12, 2016	am：GA
July 13, 2017	pm：SP
July 14, 2016	pm：SP
July 15, 2016	am：Free pm：Inauguration ceremony
July 16, 2016	90'Jog
July 17, 2016	Off
July 18, 2016	**pm：200m×10(31") R=200m(50")**
July 19, 2016	pm：SP
July 20, 2016	pm：Uphill 300m×5(FREE) R=300m
July 21, 2016	am：GA pm：SP
July 22, 2016	am：Off pm：25000m (3'40 ~ 20)+TR
July 23, 2016	Off
July 24, 2016	am：Free pm：16000m(3'10)+1000m(2'40) R=400m
July 25, 2016	am：SP pm：Off
July 26, 2016	am：SP pm：Off
July 27, 2016	**am：Free pm：400m×10(62") R=200m(65)**
July 28, 2016	am：GA pm：FREE
July 29, 2016	Off
July 30, 2016	am：Free pm：12000m(3'05)+400m(60) R=200m
July 31, 2016	am：SP pm：Free
August 1, 2016	am：SP pm：Free
August 2, 2016	am：Free pm：5000m(14'10)+3000m(8'25) R=10'
August 3, 2016	am：Free pm：GA
August 4, 2016	am：GA pm：SP
August 5, 2016	**am：Free pm：1000m×4(2'45) R=200m(75)**
August 6, 2016	pm：SP
August 7, 2016	am：8000m(3'15 ~ 10) pm：GA（NY to Rio）
August 8, 2016	am：GA pm：SP
August 9, 2016	pm：SP
August 10, 2016	pm：3000m×1
August 11, 2016	pm：SP
August 12, 2016	pm：SP
August 13, 2016	Olympic Games, 10000m 28.55.23 29th

Note. The days on which interval training was introduced are indicated in bold and under line. Self-practice: SP, rest: R, tempo run: TR, get around: GA, NY: New York, US, Rio: Rio de Janeiro, Brazil.

Measures

Training achievement score

The Training Achievement Score is a numerical value used to evaluate how well the participant performed the training tasks according to his/her envisioned execution. After completing each training session, the participants conducted a self-assessment and rated their performance on a scale from 1 to 10. A score closer to 10 indicated that the athlete was able to execute the training as imagined.

Conditioning score

For the Physical Conditioning Score, the participants self-assessed their physical condition during morning training on a scale of 1–10. The evaluation criteria included muscle tightness throughout the body during running movements, the range of motion of each joint, form balance, and ease of movement relative to running speed. All these factors were considered to evaluate the overall physical condition. A score closer to 10 indicated a better physical condition.

The Mental Conditioning Score is a self-assessment of changes in stress levels experienced by a participant during training. The stress assessment focused on four negative elements: anxiety, irritation, loss of confidence, and inconvenience. However, the stress felt by the participant when applying pressure to enhance performance was not considered a negative element and was excluded from the stress measured in this study. The evaluation method used a 10-point scale based on the participants' subjective assessment conducted after the morning training to ensure that the assessment was not influenced by sleepiness. The 10-point scale was centred at 5, with scores closer to 1 indicating more positive feelings and scores closer to 10 indicating more negative emotions, such as anxiety and irritation.

RESULTS

Training achievement score

There was a decrease in the Training Achievement Score from April to May. Although there were some fluctuations, the scores generally ranged from 10 to 8. Despite mostly showing a score of 10 throughout July, the score began to decline around July 29, 8 days before the Olympics; it did not reach 10 again (Figure 1).

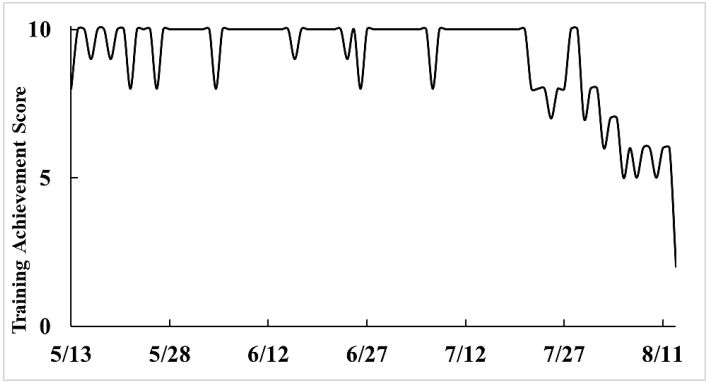

Figure 1. Training achievement.

Physical conditioning score

In general, the Physical Conditioning Score was evaluated between 7 and 10; however, on May 1 and after the final Olympic selection event on June 26, the scores were in the range of 5 to 6 due to fatigue. After the 10,000 m race on July 12, the score showed a downward trend and did not increase (Figure 2).

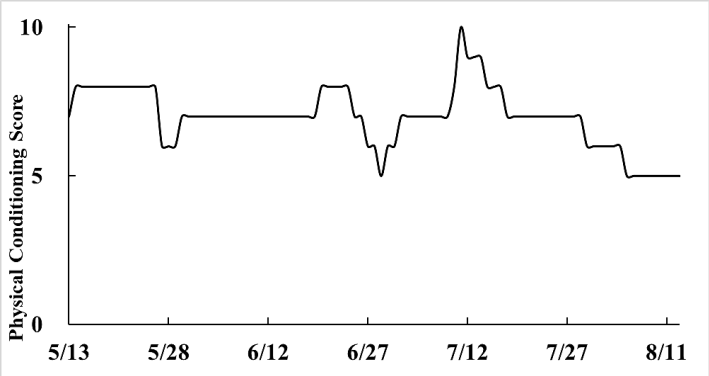

Figure 2. Physical conditioning score.

Mental conditioning score

On May 1 and from June 22 to 27, high scores were recorded, whereas on the other days, the scores appear to be generally less than 6. After July 21, the score consistently exceeded 6. As the Olympics approached (August 13), the scores increased, ranging from 7 to 9, and from August 3 onwards, the scores were even higher, ranging from 8 to 10 (Figure 3).

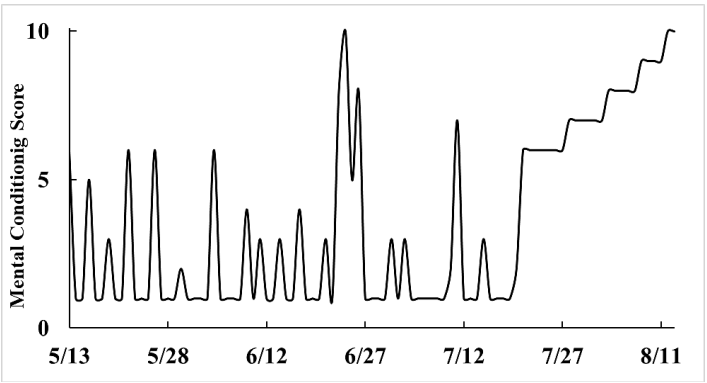

Figure 3. Mental conditioning score.

DISCUSSION

Physical conditioning

In preparation for the Olympics, two unplanned impacts on the participant's physical condition were observed: foot blisters that developed on May 1, and pain in the triceps surae that was reported on July 30. Foot blisters are common injuries among endurance athletes and are known to decrease concentration and athletic performance (Lipman et al., 2016). The foot blisters observed in this study were caused by ill-fitting racing shoes and healed quickly without a prolonged impact on the participant. As it was confirmed that there was no breakdown in form during training and the 10,000 m race on May 7, the coach determined that recovery was complete.

The triceps surae are composed of the gastrocnemius and soleus muscles; pain in the triceps surae is a common injury among athletes (Radice et al., 2017). The participant reported "*I think it's mild, but I have pain in my calf*." The condition was monitored after the morning practice on July 31, and the participant responded

to the coach's inquiry by saying, "*I'm fine*," with no requests for changes to subsequent training. Given the participant's history of achieving results in competitions, the coach believed the participant to be a self-managing athlete and trusted their words, concluding that recovery was complete. However, upon reconsidering the participants' training from July 31, it was noted that their concentration had declined. Although there were no clearly visible signs of deterioration and the participant continued to respond with "*I'm fine*," the coach refrained from probing further to avoid disturbing the participant's mental state with the Olympics approaching. This decision to not delve deeper may have led to a lack of an accurate understanding of the participant's physical condition, resulting in the athlete competing in the Olympics without achieving optimal conditioning.

A higher mutual trust in interpersonal relationship between the coach and the athlete leads to improved performance (Bakiev, 2013); therefore, it is necessary to focus on building a trustworthy environment and enhancing athletes' motivation in the coach–athlete relationship. Until now, the evaluation of the condition was based on the subjective judgments of both the coach and athlete; however, under high-pressure situations, neither the coach nor the athlete can make the same judgments as they would under normal circumstances. Therefore, objective materials that can assess the condition without being influenced by the subjective views of coaches and athletes are essential.

Mental conditioning

Participants' mental changes are believed to be influenced by both physical conditions and environmental changes. Regarding the participants physical condition, his stress levels increased when traumatic blisters were sustained. Although there was no observed increase in stress levels on July 30, when triceps surae pain was reported, there was an increase in stress levels 2 days earlier on July 28. This suggests that the participant may have been dealing with pain in the triceps surae and deliberating before reporting it to the coach. As injuries can easily lead to depression and anxiety (van der Vlegel et al., 2022), even minor injuries can become a source of anxiety regarding the race, leading to a loss of confidence. In this context, it is reasonable to consider that even mild pain in the triceps surae had an impact on the participants' mental state.

Regarding the environmental changes, the participants stress levels increased on August 3, when the participant began traveling to the Olympics, and on August 8, upon arrival in Rio de Janeiro. While there was anxiety and nervousness about the Olympics, the unfamiliar overseas environment likely impacted participants' mental state. The desire to succeed in performance is known to increase stress levels (Fletcher and Scott, 2010, Thelwell et al., 2017). In discussions with the participant on the post-Olympic outcomes and reflections, they stated, "*I didn't feel stress caused by the overseas environment, but since I didn't achieve results at the Olympics, I might have felt stress without realizing it*." The participant had limited experience and had only competed in overseas races on 10 occasions over 4 years leading up to the Olympics. Given that mental toughness (challenge, commitment, and life control) has a significant positive correlation with age and sports experience (Nicholls et al., 2009), it can be inferred that gaining more experience abroad is necessary. As a specific countermeasure, it is crucial to understand the causes of stress through overseas experiences, such as language barriers, food, living conditions, time differences, and long-duration travel, and to maintain a coping list tailored to these stressors. Maintaining this coping list has been shown to alleviate negative emotions caused by stress (Nicholls et al., 2007). By doing so, athletes can compete in overseas races with a sense of familiarity similar to that in domestic races, which is crucial for them to perform at their best.

Training

Top athletes around the world travel internationally throughout the year, increasing their race experience while enhancing their ability to adapt to long-distance travel, time zone changes, and various environments in which they compete. Additionally, in terms of training, they consistently engage in HIIT (Billat, 2001). Furthermore, teams should comprise coaches specializing in training, physical conditioning, medical support, and mental coaching to create a comprehensive support system that enables athletes to continue HIIT. In contrast, for Japanese athletes, participation in overseas races is considered special; it is not feasible to plan and compete with the same familiarity as domestic races. Just as being accustomed to domestic competition venues is advantageous for performance, it is necessary to become familiar with overseas environments to perform well internationally. Therefore, Japanese athletes need to actively engage in overseas training camps to eliminate their exceptional perception of overseas competition.

High-intensity training has been reported to improve running economy, which is crucial for performance (Llanos-Lagos et al., 2024). Running economy is defined as the energy expended at sub-maximum running speeds and is considered a critical factor in running performance (Llanos-Lagos et al., 2024). Therefore, there has been a shift from prioritizing quantity-based training to quality-based training, recognizing its importance in preparation for the Olympics. This shift in approach, coupled with the lack of adequate support, led to pain in the triceps surae on July 30; however, during preparation for the Olympics, in the 10,000m race on July 11, a relatively comfortable performance of 27:48.35 min was achieved, which was close to his personal record of 27:42.71 min. Thus, it was inferred that the direction of the training was not incorrect. To compete at the level of top international athletes in Japan, it is necessary to maintain the direction of training that ensures quantity without sacrificing quality, and to enhance the support system of the team to continue HIIT.

CONCLUSION

In Japan, the introduction of HIIT is crucial for competing with top international athletes; however, because HIIT increases the risk of injury, it is also necessary to enhance non-running physical strengthening and care. Additionally, it is desirable to form a team of coaches specializing in physical conditioning, medical support, and mental coaching to support athletes. The causes of mental disruption include injuries and environmental changes; therefore, it is desirable to prevent injuries through objective evaluations using metrics. Additionally, coping strategies tailored to stress can help athletes acquire a sense of familiarity, even in overseas environments, which is crucial for them to perform at their best.

AUTHOR CONTRIBUTIONS

Idea: N.N. and S.I. Concept: N.N. and S.I. Design: N.N. and S.I. Data collection: N. N. Data analysis: N.N. Writing article: N.N. Supervision: S.I.

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No potential conflict of interest was reported by the authors.

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